Southern Journal of Engineering & Technology Vol. 02, Issue 01, 2024

Power Quality Improvement of Hybrid System in Grid and Islanded Mode of Operation Using DSTATCOM-BESS

Mashhood Bin Abdul Mughni, Tauheed ur Rahman, Umair Fayyaz, Muhammad Saad Khan
Bahauddin Zakariya University, Multan, Pakistan

Abstract: Electrical energy generation from renewable energy sources is increasing on a day-to-day basis due to the massive increase in global warming as a result of the extensive use of conventional fuel-based energy sources. However, these renewable sources are much dependent on atmospheric conditions, and depending solely on such sources for power generation can be the cause of system-wide disturbances in power networks. These integrated intermittent renewable sources also add various power quality issues to the entire grid due to their nonlinear nature. However recent advancements in power electronics offer many practical benefits that can regulate this discontinuous behavior of renewable systems, especially that of Solar and Wind. In this paper, such power quality improvement technique for Wind-Solar coupled systems is studied in grid-connected and islanded modes of operations. This paper focuses on voltage regulation, Harmonic distortion, and frequency imbalance nature of the power network in the presence of solar and wind sources. The proposed scheme consists of a most advanced type of power electronic compensator namely Distribution Static Compensator (DSTATCOM) energized with Battery Energy Storage System (BESS). The proposed system is applied and simulated in MATLAB/Simulink software. The results attained from this proposed method indicate that DSTATCOM performs efficiently to enforce grid coordination rules in grid-connected and islanded modes according to IEEE standards.

Keywords: Power Quality, DSATCOM, BESS, Hybrid Energy Systems, Point of Common Coupling (PCC)

Email: mashhood2020@gmail.com

1. Introduction:

The industrial revolution and increasing population during the last three decades has led to substantial and extraordinary inventions that have introduced new technologies, especially in the power sector. The massive use of power in commercial and noncommercial areas is the basis of an unimaginable growth in the utilization of energy and more precisely

Electricity. This ensured an enormous increase in supply–the demand gap in electricity production. The insufficiency of Traditional energy sources, significant hikes in fossil fuel prices, and subsequent toxic emissions produced as a result of utilizing these Carbon composite fuels have resulted in the power generation from such sources being an unsuitable and unviable option. It is forecasted that such a huge disparity in production and consumption of electricity will tend to increase exponentially lest it is satisfied with the help of some other methods of power production. The intermittent resources i.e. water, wind, sea, sun, and biomass have demonstrated themselves as a useful substitute and a more considerable choice than conventional energy resources. However, the nonlinear and atmospheric dependence of such sources is a major drawback for such new sources. This led to a new concept in power systems known as “Hybrid Power Systems”. The fusion of one or more intermittent resources is known as the Hybrid Energy system. The hybrid RES (HRES) can be connected with the grid in the form of a distributed system to meet load requirements or they can be a standalone system in the island formation. From the RES standpoint, at present the most advanced renewable resources are Photovoltaic (PV) and wind energy conversion systems (WECS) GOUD & Reddy, (2020).

But the problem is that our existent power-generation system consists of large power plants with centralized controls. On the other side, Renewable is intermittent, independently controlled, and distributed. That is the reason that modifying our existing power infrastructure to operate efficiently with renewable sources can result in many complexities. While the concept of integrating renewables is already in the market, the questions still are on the table how to enhance the system's flexibility and maintain its reliability? how to improve the efficiency of such distributed power systems? and how the concept of power quality will act for the future’s smart grid. These are some of the important considerations that should be answered first before deploying huge capital over the next few decades on preserving and growing power networks to get the entire benefits of renewable energy generation Liang, (2017).

Power quality is described as the conditions that are specified for the system’s electrical parameters to maintain the power network’s intended operation and to provide lossless electricity to the consumer. There are various types of power quality issues such as voltage sag and swell, voltage and current transients, unbalanced load, harmonics at the load end, poor power factor, etc. The voltage level is affected when the load demand increases owing to the excessive burden on the line A. Sharma & Thosar, (2018). Inferior power quality can cause a loss in productivity, can destroy data, and cause damage to equipment. An approximate sum of all the losses in the U.S. indicates that companies waste about 26 billion dollars on electrical quality-related issues every year Mahfoud, Guzun, Lazaroiu, & Alhelou, (2019).

Gayatri, Parimi, and Pavan Kumar (2018) have reviewed the deployment of various compensation devices for the rectification of reactive power problems in micro grids. They have analyzed that capacitor banks and other switched devices like Thyristor Controlled Capacitors (TCS) and Thyristor Controlled Reactor (TCR) are only capable of rectifying some power quality issues. They have utilized different LC filters to reduce harmonics and raise the system's power factor while reducing the number of capacitors. However, the significant issues that arise with this approach such as bulkiness, resonance, and fixed compensation are the main hurdles with these conventional compensators. They have concluded that a modern power electronics-derived solution named Flexible AC transmission systems (FACTS) is a powerful technique to provide compensation to micro grids. Modern smart grids use FACTS devices with their fast control methodologies to enhance the performance of integrated renewable. They work by supplying or absorbing reactive power for voltage control at the load bus (Gandoman et al., 2018),(Ashok Kumar & Indragandhi, 2020),(Urquizo, Singh, Kondrath, Hidalgo-León, & Soriano, (2017).

Dash and Swain (2018) have analyzed a FACTS device called a Dynamic Active Compensation System (DACS) which consists of the Static Synchronous Series Compensator (SSSC) with a Static Synchronous Compensator (STATCOM) to mitigate power quality issues in grid-integrated solar system. Kasa, Ramanathan, Ramasamy, and Kothari (2016) have introduced a Dynamic Active Power Filter (DAPF) which is provided with I cosine ANFIS control. The device has performed efficiently to enhance the power quality of the grid at the source end. In their work, the grid is integrated with wind and solar systems. Mahela and Shaik (2016) have studied the effectiveness of DSTATCOM with a synchronous reference frame-based controller. They have utilized battery energy storage for DSTATCOM in place of conventional storage capacitors. They have tested the system by simulating grid disturbances and by penetrating the wind energy in the grid. In their work, DSTATCOM has acted efficiently to resolve different power quality issues that arise due to grid instabilities like voltage swell and voltage sag, variation in load, and due to tripping and re-energizing of feeders. Mishra and Ray (2016) have suggested a new optimization technique for Photovoltaic energized Distribution Static Compensator (PV-DSTATCOM). They have proposed a technique called JAYA to regulate the constants of the PI controller and to provide filter parameters for the system. Ramya, Ganapathy, and Suresh (2017) have proposed a DSTATCOM with cascaded multilevel inverter technology and Dynamic Voltage Restorer (DVR) to counteract voltage dip in the electrical distribution system. They have proposed a multilevel topology for DSTATCOM which is based on isolated DC energy storage and with a limited count of switches. They have utilized DVR to provide the voltage that is in synchronization with the system voltage and D-STATCOM is used as a current compensating device. They have used the combination of both devices to deal with multiple power quality issues such as voltage dip, voltage rise, and interruption. Reddy (2020) has studied DSTATCOM in Single Phase Micro grid which is utilized for reactive power compensation of the system during different modes of operation. In his paper, he studied reactive power compensation techniques for normalizing the power flow in an electrical network and eliminating the voltage dip in the system. He has concluded that communication devices at the distribution end can enhance the effectiveness of DSTATCOM to balance the voltage and power flow in the lines. A. Sharma and Thosar (2018) have studied a relative study of three distinct control strategies (Unit Template method, Instantaneous Reactive Power Theory (IRPT), and Synchronous Reference Frame Theory (SRFT)). They have found these techniques efficient for DSTATCOM to get the desired reactive power compensation and harmonic reduction in the distribution system. Hossain, Tür, Padmanaban, Ay, and Khan (2018) have discussed the attributes of power quality for distributed energy systems that utilize intermittent energy sources, that as solar and wind. They have conducted a detailed analysis of the problems with power quality in such energy systems. They analyzed different power quality items, with an overview of basic standards, and finally proposed a custom power device called STATCOM for power quality mitigation in distributed resources.

Much of the literature as reviewed by the researchers focuses on power quality in hybrid systems either only in grid-connected mode or in islanded mode of operation. But the future smart grid will be much more resilient and can function as grid-dependent at one instant and as a micro grid at another instant due to the sudden failure of the power grid. This research mainly focuses on this research gap by studying the power quality in the hybrid renewable system in both configurations i.e. grid-connected and islanded. The system proposed by the researchers can function efficiently both in an islanded and grid-connected mode of operation.

1 Modelling of the System:

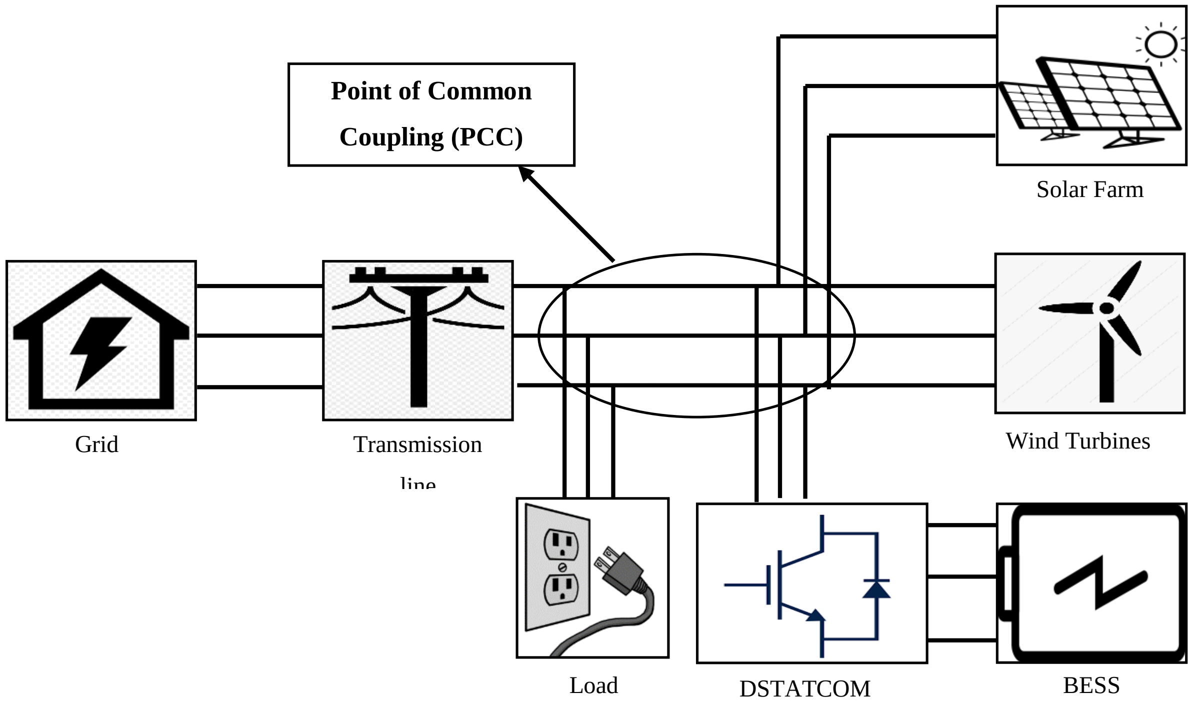

Fig.1 Schematic Illustration of simulated system

The schematic diagram of the system is shown in Figure 1. The proposed scheme is tested in MATLAB Simulink. This subsection explains the major parts of the system.

1.1 Grid:

The grid is simulated using a three-phase source in series with inductances that are mutually coupled between the phases. The grid supplies 11KV at 50Hz frequency. The three-phase voltage source can also be programmed to produce any variation in voltage, frequency, and phase.

1.2 Transmission line:

The 30 km transmission line is modeled as a pi-section line. RLC elements of the line are modeled in Simulink using hyperbolic corrections.

1.3 Solar farm:

The solar farm is simulated in Simulink by using 5 arrays of PV panels. Each array consists of sixty-six parallel strings with five series connected modules per string. Each array generates 100 KW. The total theoretical output from the PV farm is therefore 500 KW. Each PV array is connected to an MPPT controller. The MPPTs use the "Perturb and Observe" method to get maximum efficiency of the PV array. The MPPT controller output is connected to the DC bus of 500V. The DC output of arrays is then converted into AC using VSC (Voltage Source Converter).

The VSC inverts 500V DC into 260V AC while keeping the power factor of the solar system at unity. A 500 KVA 260V/11KV step-up transformer is used to balance the solar system voltage with the grid.

1.4 Wind Turbines:

Two wind turbines each producing 1.5 MW power are coupled at Point of Common Coupling (PCC). Both wind turbines are based on a Doubly Fed Induction Generator (DFIG) which has a wound rotor and an AC/DC/AC converter with PWM control. The stator winding is directly supplied with a 50 Hz supply while the rotor winding is fed with variable frequency by the use of converters.

1.5 BESS-DSTATCOM:

The Battery Energy Storage System (BESS) is utilized as a source of energy to preserve the stability of the grid. In this configuration, DSTATCOM is energized with BESS and is coupled in parallel with the system to maintain the reactive power of the system. The reactive and active power exchanged by the DSTATCOM-BESS with the grid is given by equation 1 and equation 2:

$$P = \frac{VpccVc \sin \alpha}{X} \tag{1}$$

$$Q = \frac{Vpcc(Vpcc - Vc \cos \alpha)}{X} \tag{2}$$

where V_c is the VSC-based inverter voltage; P defines the active power supplied or taken by the DSTATCOM from the grid whereas Q defines the reactive power exchanged with the grid. V_{pcc} is the voltage measured at the PCC; α defines the angle between V_{pcc} and V_c while X is the reactance of the coupling inductor V. Sharma & Gidwani, (2019).

The proposed DSTATCOM as shown in Figure 2 comprises two VSCs in bridge configuration which are supplied with a battery energy source, a filter that is used to eliminate the harmonics, and coupling transformers that are used to couple the DSTATCOM with the grid system. The proposed DSTATCOM can be modeled for low voltage levels such as 230V as compared to the original line voltage of 11 KV which is the case with the DSTATCOM proposed in similar studies Patel, Venkatraman, Raju, & Kumar, (2021), Kumar, Swarnkar, Gupta, & Niazi, (2017). Furthermore, the three transformers connected with each phase also reduce triplen harmonics which arise due to the switching action of DSTATCOM.

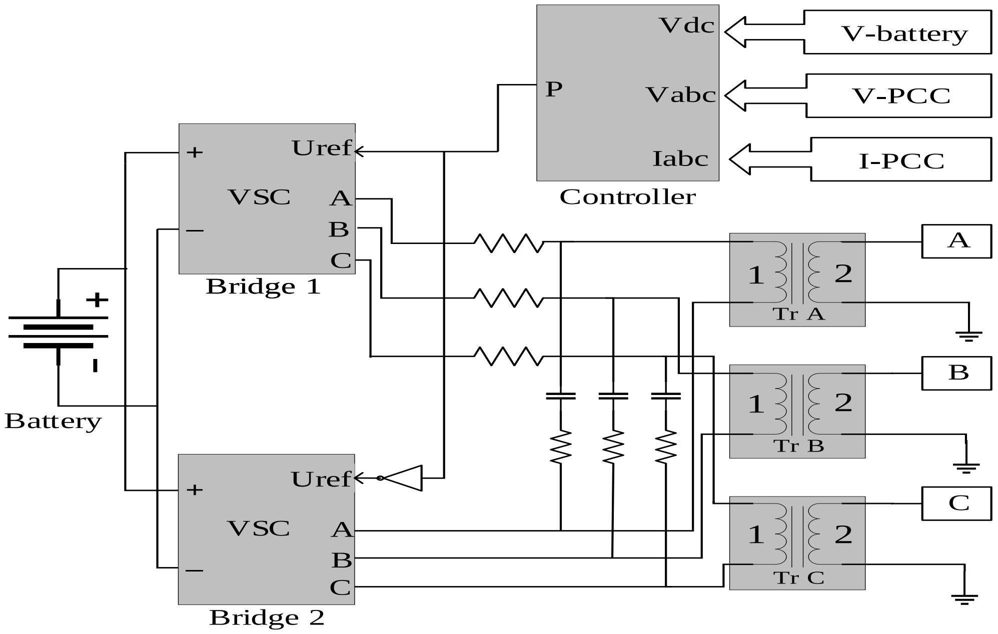

Fig. 2 VSC based DSTATCOM-BESS Hussain, Hussain, Raza, & Siddique, (2019)

1.5.1 DSTATCOM Control Scheme:

DSTATCOM Control scheme uses three-phase currents and voltages to compute corresponding d-q axis components of currents and voltages. The d-q axis components are calculated using equation 3.

$$\begin{bmatrix} U_d \\ U_q \\ U_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin(\omega t) & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos(\omega t) & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix}$$

(3)

The magnitude of the voltage at PCC is calculated by equation 4.

$$Mag\ V = \sqrt{{V_d}^2 + {V_q}^2} \qquad (4)$$

This voltage magnitude and reference voltage (1 pu) are then compared to generate an error signal through a PI controller. This signal is termed an I_q reference signal. This signal is in turn compared with the measured I_q signal at the PCC to generate an error signal. The error signal given to the PI controller is calculated by using Equation 5.

This error signal is then used to generate a Pulse Width Modulated (PWM) signal

$$V_{error} = I_q - I_{q-ref}$$

(5)

which is then used as a switching indication for the IGBTs of VSC. It can be concluded from equations 3-5 that DSTATCOM with its d-q-based PI Controller is capable of correcting system parameters by employing a negative feedback system.

1.6 Load:

The load is simulated as a nonlinear load with requirements for active power of 4MW and reactive power of 2.26 MVars (Positive Var's).

The detailed parameters of system modeling are given in the Appendices.

2 Proposed methodology:

The efficiency of the proposed device: DSTATCOM with Battery Energy Storage Systems (BESS) is studied in two configurations: Grid-connected mode and islanded mode of operation. During each mode, different disturbances are injected into the proposed system to verify the validity of the proposed scheme. The disturbances injected are:

1. Injecting voltage sag and voltage swell from the grid of ± 0.3 pu to check the efficiency of DSTATCOM to mitigate these disturbances. The parameters such as solar insolation and wind speed are kept constant at 1000 W/m^2 and 11m/sec respectively during the simulation of voltage sag and swell from the grid.
2. Varying wind speed and solar insolation which affect the output of wind turbines and solar panels respectively. At 0.5 seconds, solar insolation is reduced to 200 W/m^2 from 1000 W/m^2 and Wind speed is reduced to 8 m/sec from 11m/sec. At 1 second, the solar insolation and wind speed are again changed to their original values of 1000 W/m^2 and 11 m/sec. During this time, the grid voltage is maintained at 1 pu.

For highlighting the effectiveness of DSTATCOM, the power factor correction capacitor is also used to provide a comparison of active and passive compensation in such scenarios. The study only focuses on Voltage regulation, Total Harmonic Distortion (THD), and frequency imbalance issues in power systems.

3 Results and Discussions:

3.1 Grid Connected Mode of Operation:

In Grid-connected mode, the Solar farm, Wind farm, and grid are connected with the load at the Point of Common Coupling

(PCC). It is found that DSTATCOM not only performs the function of the voltage regulation of the system which drops due to the high reactive power demand from the load but DSTATCOM also controls the voltage of the system between the event of voltage sag and swell. Voltage sag and swell both are simulated from t=0.2 to 0.5 seconds to check the efficacy of DSTATCOM in the event of a fault. The results obtained for voltage sag, swell, and solar and wind parameters are given below.

3.1.1 Voltage Sag from the grid:

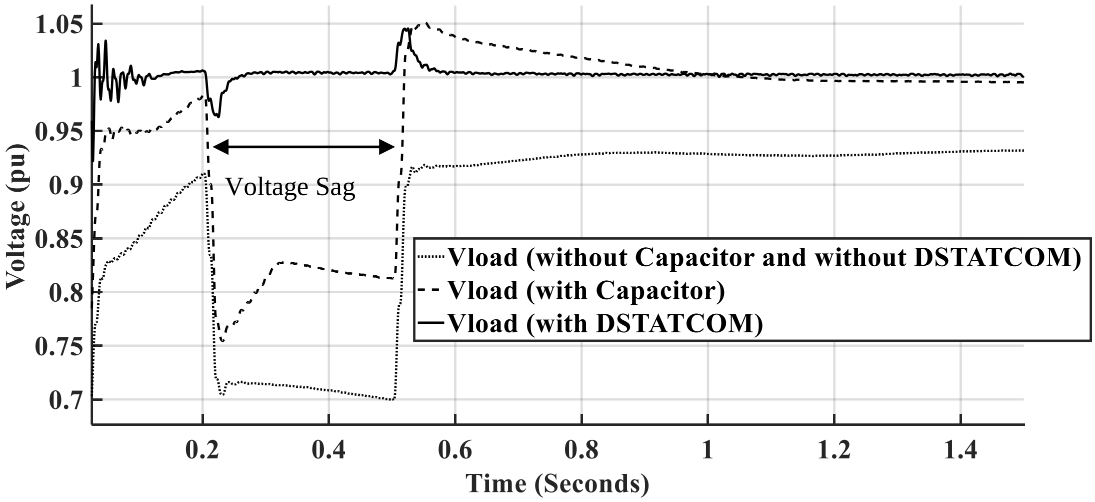

Fig. 3 Comparison of voltage regulation capability of the capacitor and DSTATCOM in the event of sag

The voltage sag is simulated from t=0.2 to 0.5 seconds by reducing grid voltages to 0.7 pu.

During this period, DSTATCOM acts as a reactive power source and maintains the load voltage at 1pu. When DSTATCOM is connected to the system, the voltage fluctuation is only confined to 0.05 pu window, above and below 1 pu, below the permissible voltage fluctuation level according to IEEE Std 1250-2018. The comparison of the voltage compensating ability of DSTATCOM and capacitor in the event of voltage sag is shown in Figure 3.

It can also be observed from Figure 4 and Figure 5 that the THD of the system drops to 2.59% after the voltage sag is injected from the grid at 0.2 seconds. But DSTATCOM reduces this harmonic distortion to 1.41% which is acceptable under IEEE standards.

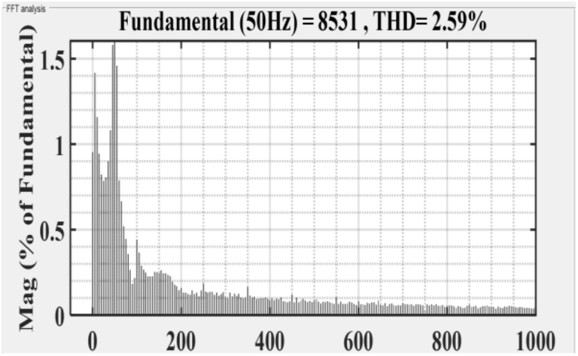

Fig. 4 THD due to voltage sag without DSTATCOM

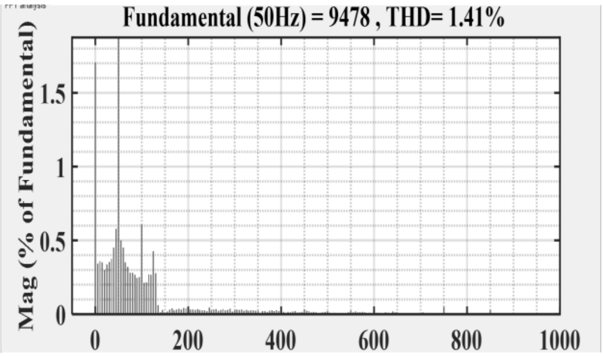

Fig. 5 THD due to voltage sag with DSTATCOM

3.1.2 Voltage Swell from the grid:

The voltage swell is replicated by stepping the grid voltages from 1 pu to 1.3 pu during 0.2 to 0.5 seconds. To overcome this voltage swell, DSTATCOM again acted as a fast compensating device by compensating the reactive power of the system and suppressing the extra line voltages. It is also evident from the results that a traditional compensating device such as a capacitor is incapable of dealing with this issue which arises due to sudden demand of lagging var's from the regulate the voltage to the grid. The comparison of the voltage compensating ability of DSTATCOM and capacitor in the event of voltage sag is shown in Figure 6. It is evident from Figure 7 and Figure 8 that DSTATCOM also reduces the THD of the grid. In this scenario, DSTATCOM acts as a reactive power source from 0 to 0.2 seconds but at 0.2 seconds due to sudden voltage swell, DSTATCOM acts swiftly to provide inductive var's to the system to offset that high voltage, and after 0.5 seconds again switches back to a capacitive reactive power source to

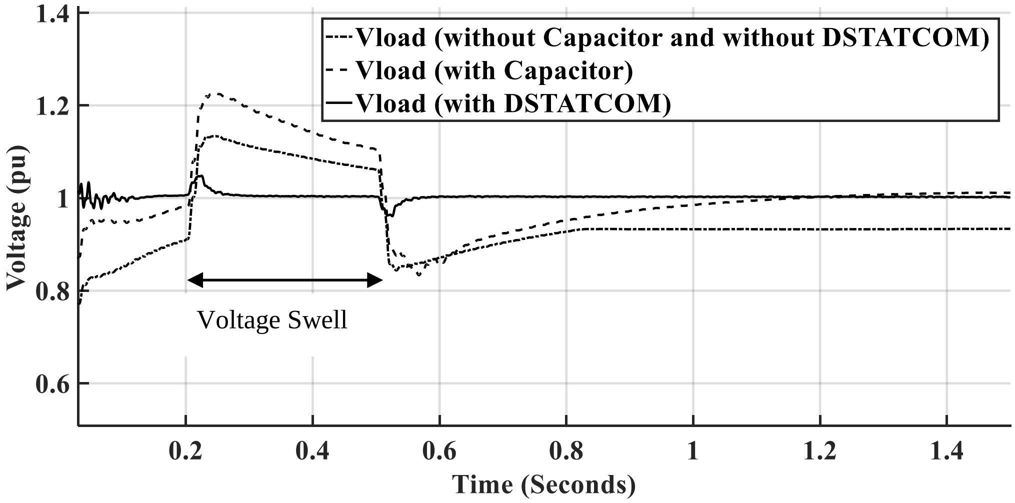

Fig. 6 THD due to voltage swell with

load current to 1.44% which was previously 2.42% due to voltage swell.

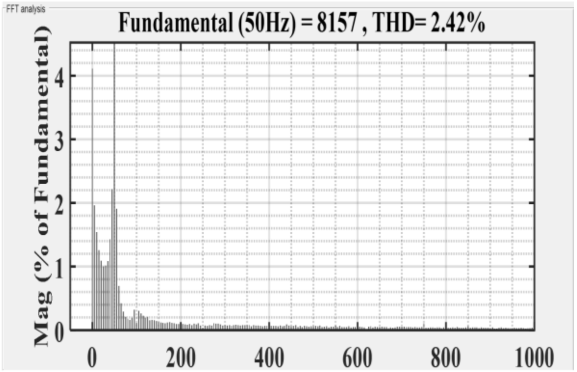

Fig. 7 Comparison of Voltage regulation capability of the capacitor and DSTATCOM in the event of a

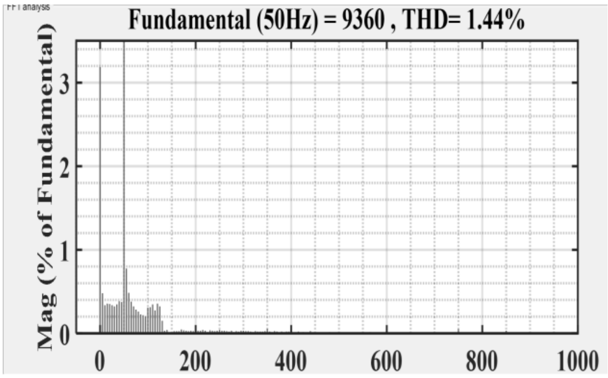

Fig. 8 THD due to voltage swell without

3.1.3 *Frequency Regulation:*

It is evident from Figure 9 and Figure 10 that frequency is very much nonlinear in the absence of DSTATCOM. But when we connect DSTATCOM with the system, frequency is regulated to 50 Hz and all fluctuations die out due to the fast-compensating capability of DSTATCOM. These load parameters are observed while simulating the system with a voltage dip of -0.3 pu from 0.2 to 0.5 seconds.

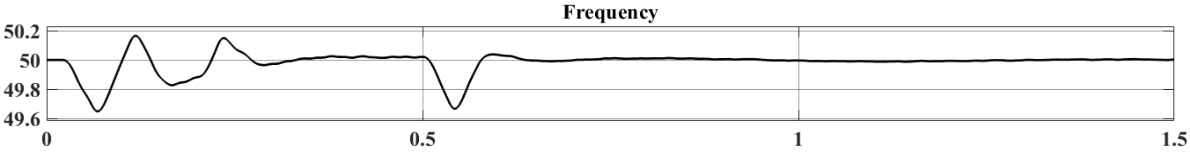

Fig. 9 Frequency without DSTATCOM

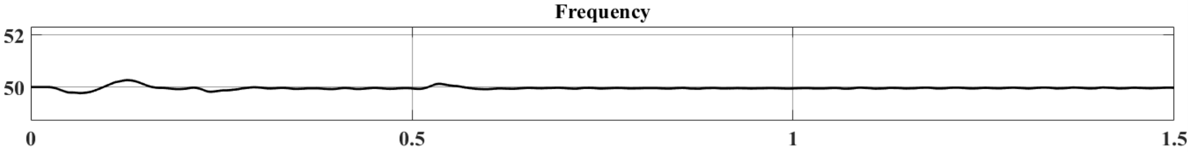

Fig. 10 Frequency with DSTATCOM

3.1.4 *Variation in solar insolation and wind speed:*

The solar insolation and wind speed are varied to check the ability of DSTATCOM to counter atmospheric phenomena. From 0.5 second to 1 second, the solar insolation for all 5 solar farms is reduced to 200 W/m^2 from 1000 W/m^2. Similarly, wind speed for wind turbines is reduced to 8 m/sec from 11 m/sec during this time. During this time, sudden deterioration in Voltage regulation and Total Harmonic distortion (THD) is observed at the load end.

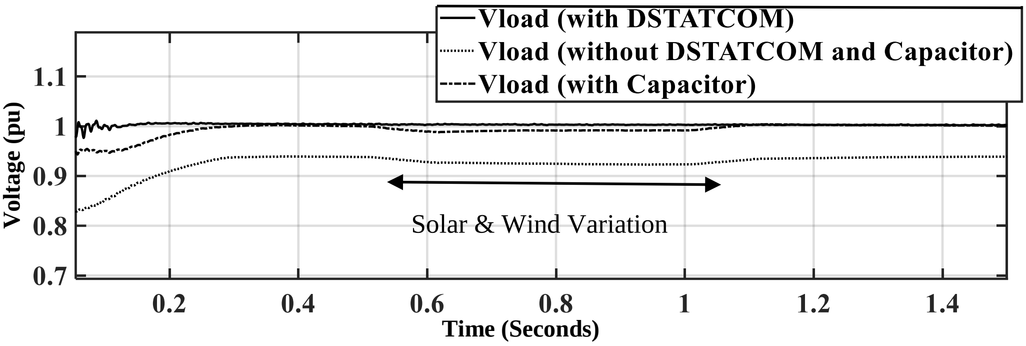

Fig. 11 Comparison of Voltage regulation capability of DSTATCOM and capacitor due to sudden change in solar insolation and wind speed

As shown in Figure 11, It is observed that without any compensating device used at the load end, the voltage profile of the load is not acceptable according to international standards. With the capacitor added to the system, the voltage of the system is maintained but it is not capable of sustaining the voltage during changing solar and wind parameters. However as shown in Figure 5, DSTATCOM maintains the voltage at 1pu during such environmental variations.

The Total Harmonic Distortion (THD) of the load currents is also observed after 0.5 seconds to check the capability of DSTATCOM to reduce harmonics in the event of solar and wind variation. As shown in Figures 12 and 13, DSTATCOM reduced such harmonics levels from 0.71% to 0.38%.

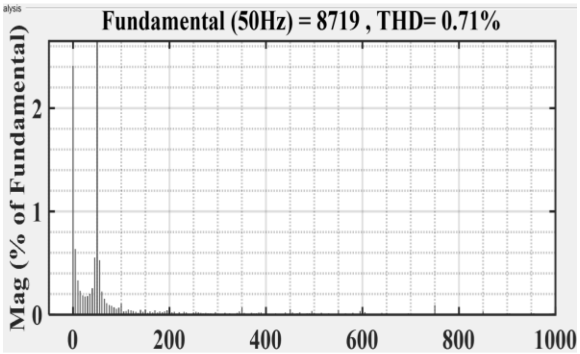

Fig. 12 THD due to solar wind variation without DSTATCOM

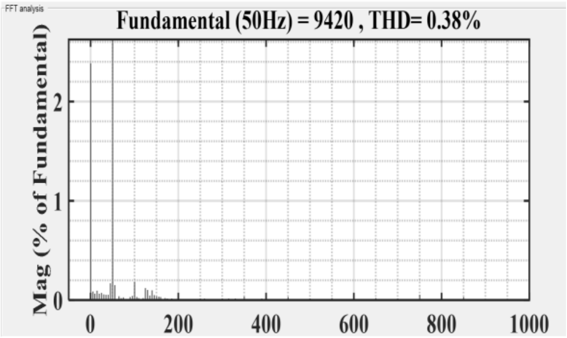

Fig. 13 THD due to solar wind variation with DSTATCOM

3.2 Islanded Mode of Operation:

During islanded operation, Gird is disconnected from the system. Only wind turbines and solar farms keep supplying the power to the Load. In this state, the grid regulations enforced by the grid due to its high inertia are absent. During islanded mode, the solar insolation and wind speed are varied according to the mentioned criteria to check the capability of DSTATOM to enforce grid regulations in the event of the formation of a power island.

3.2.1 *Voltage Regulation:*

As shown in Figure 14, DSTATCOM keeps the voltage level of the load at 1 pu the solar and wind variations that are imposed on the system.

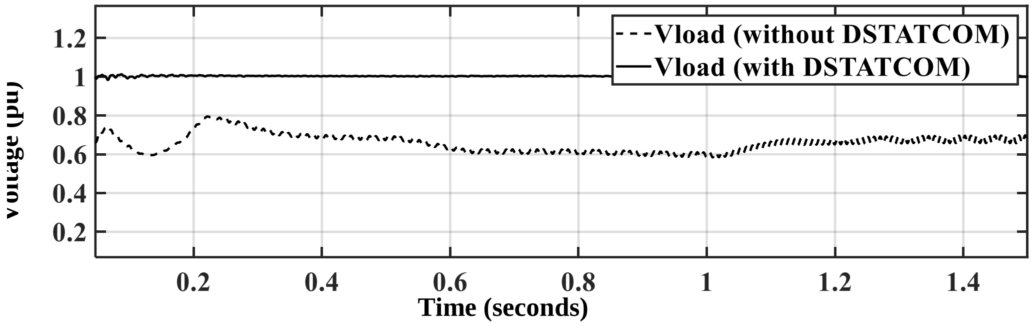

Fig. 14 Comparison of Voltage regulation with and without DSTATCOM

in the absence of the grid and provides the essential compensation to the load that was previously provided to the system by the grid. DSTATCOM maintains the load voltage at 1 pu despite the absence of a power grid. It is also further observed that from 0.5 to 1 second due to a sudden reduction in solar

3.2.2 *Frequency regulation:*

It is observed that the power island is incapable of regulating the frequency in sources and rose abruptly when the wind

insolation and wind speed, frequency dipped due to a decrease in power output from the two

3.2.3 *Total Harmonic Distortion:*

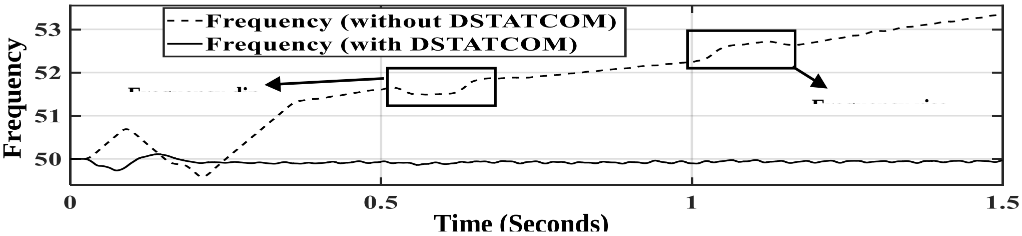

Fig. 15 Comparison of frequency regulation with and without DSTATCOM

speed and solar insolation came back at nominal values of the system. However, DSTATCOM handles these irregularities very efficiently and maintains the frequency of the system at 50 Hz. A comparison of the frequency regulation ability of DSTATCOM is given in Figure 15.

When DSTATCOM is not connected with the system, the THD of the load current is very high, much higher than the acceptable range of 3% as stated in the IEEE 1250 std. But DSTATCOM reduces this THD to a much lower level of 2.72% which is acceptable under IEEE standards. The THD of the system is calculated after 0.5

seconds to consider the consequence of solar and wind variation on the load. A comparison of THD of load current in islanded mode is shown in Figure 16 and Figure 17.

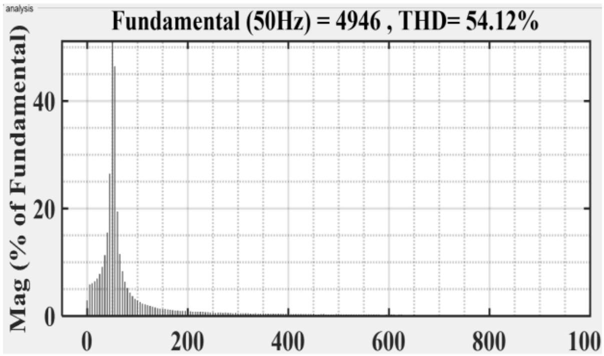

Fig. 16 THD of load current in an islanded mode without DSTATCOM

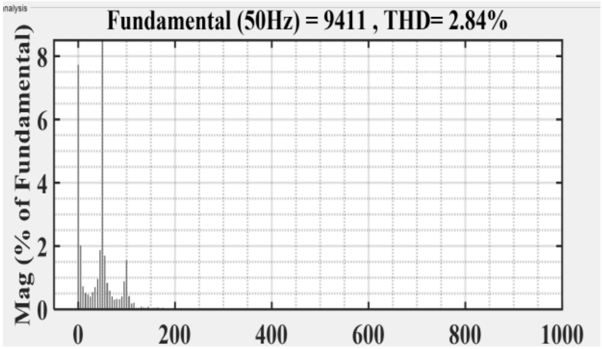

Fig. 17 THD of load current in islanded mode with DSTATCOM

4 Validation of Proposed Technique:

A similar study was conducted by Samal and Hota (2017) with another well-known FACTS device known as UPQC (Unified Power Quality Conditioner). They simulated a micro grid comprising Solar PV fuel cells and Wind Power turbines. They studied the THD and voltage regulation features of UPQC in the grid-connected and micro grid mode of operation. When compared with their result, it is found that DSTATCOM is much more effective than UPQC in suppressing THD in both grid-connected and islanded modes of system operation. The major improvements obtained with DSTATCOM are described in Table I.

Table I Comparison of THD performance of UPQC (Samal & Hota, 2017) and DSTATCOM

Different loading conditions	THD with UPQC as given in (Samal & Hota, 2017)	THD with DSTATCOM in the present study
In Grid-connected mode	3.31%	1.41%
In Islanded mode	3.48%	2.84%

5 Conclusion:

In our work, the Distribution Static Compensator (DSTATCOM) is found to be an efficient device for controlling system parameters such as Voltage regulation, Frequency imbalance, and THD at the load end. DSTATCOM has proved its efficiency in dealing with such power quality phenomena in grid-connected mode and islanded mode of operation. The proposed scheme is tested by injecting turbulences such as voltage sag and swell from the grid and solar insolation and wind speed variations for the solar and wind farms. It is found that in all cases DSTATCOM maintained the load voltage at 1 pu while it also reduced the THD of the system and kept it below the minimum threshold as stated in multiple international standards. In islanded mode, when there is an eminent need for a frequency regulating device, DSTATCOM regulates the frequency of the power island at 50 Hz. Furthermore, DSTATCOM results are also compared with another FACTS device known as UPQC and it is found that DSTATCOM is much more efficient in suppressing system harmonics than UPQC. From our results, it can be concluded that DSTATCOM with its fast controls can be the best solution for enforcing grid regulations on nonlinear systems such as that comprising solar and wind.

This research work can be extended further for studying the effect of different kinds of short circuit faults in solar wind hybrid systems and the role of DSTATCOM in providing LVRT (Low Voltage Ride Through) Capability to sustain such faults according to the requirements stated in various grid codes.

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6 Appendices:

Table II Detailed system parameters

System Parameters	Values
Transmission line (30 km)	Positive/zero sequence resistance = [0.1153 0.413] Positive/zero sequence capacitance = [11.33e-009 5.01e-009] Positive/zero sequence inductance = [1.05e-3 3.32e-3]
Compensating capacitor	Output negative var’s = 2.25 MVAR
Three-phase RLC load	Nominal Voltage and frequency = 400V and 50 Hz. Active power = 4 MW Capacitive reactive power Q_C = 733 KVAR Inductive reactive power Q_L = 3 MVAR
DFIG Wind turbines	Nominal voltage and frequency = 575V and 50 Hz Number of wind turbines = 2 Nominal power output for 1 turbine = 1.5 MW Wind speed at nominal speed and Cp Maximum = 11 m/sec
Solar farm	Solar module simulated = Sunpower SPR-305E-WHT-D Solar cells temperature = 40°C Normal irradiance = 1000 W/m^2
Solar Inverter	Two DC link capacitors are connected in series across the inverter with each of 100 mF. Nominal DC bus voltage = 500V Nominal frequency at inverter output = 50Hz L type filter at inverter output with series L= 1 mH and R= 0.5μΩ and Capacitor connected across the load with 50 KVAR.

Table III DSTATCOM parameters with Battery Energy Storage System (BESS)

System Parameters	Values
DSTATCOM	AC voltage set point Vref = 1pu.

controller	DC Voltage setpoint = 18000V. Vdc regulator gains: Kp= 0.001, Ki= 0.00015 Vac Regulator gains: Kp = 0.55 , Ki= 50 Current regulator gains: Kp= 2, Ki=1
Coupling transformer	Three coupling transformers (one in each phase) Nominal power for a single transformer = 1MW. Frequency =50 Hz.
Inverter bridge (two bridges)	Snubber resistance Rs (ohms) = 0.1 MΩ Snubber capacitance Cs (F) = inf
Battery Energy Storage System (BESS) (Lithium-ion battery)	Initial State of Charge = 83.33%. Rated capacity (Ah) = 166.67 Ah. Nominal Voltage = 18000 V